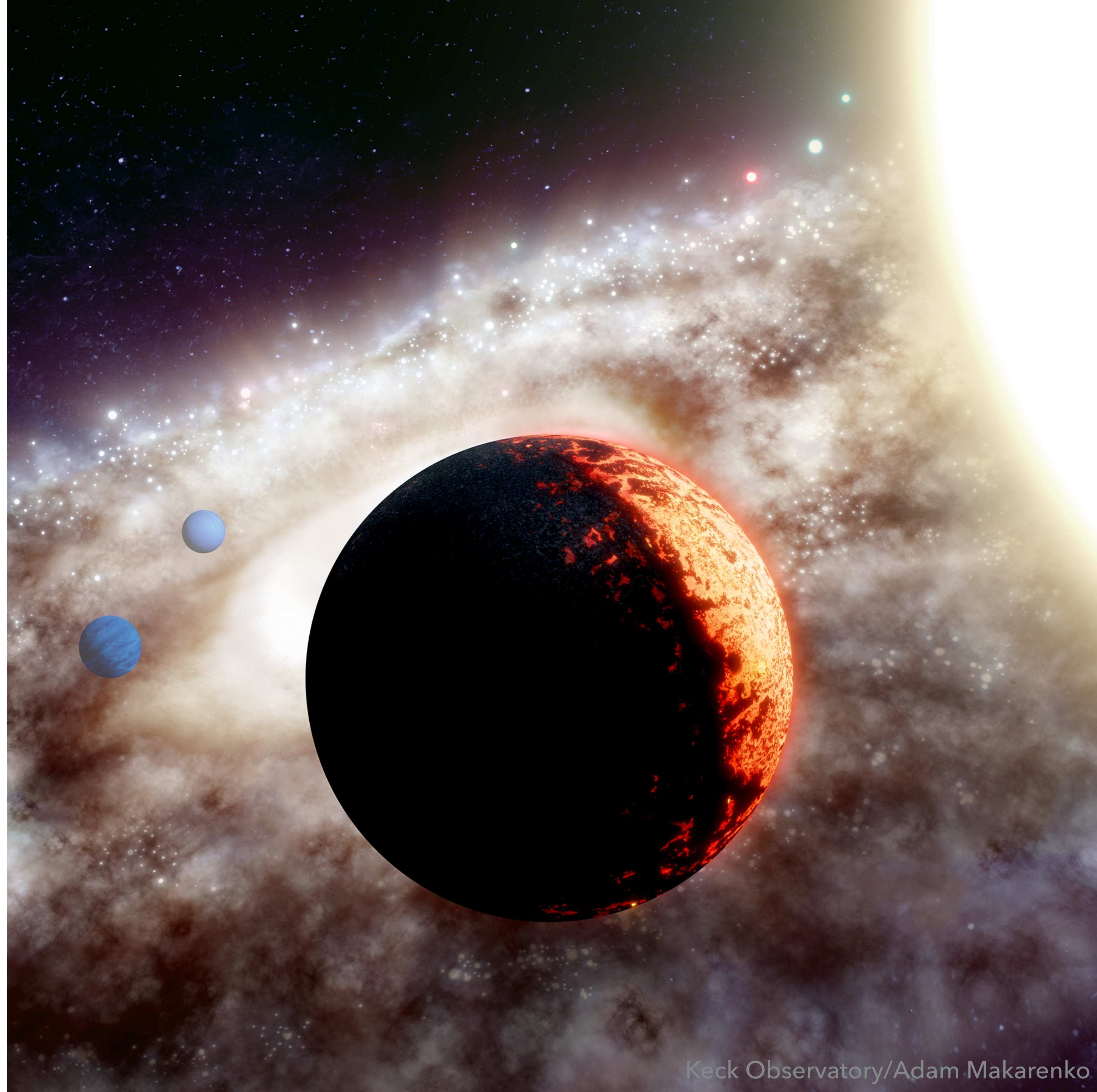


A rocky planet from the dawn of the Milky Way Galaxy

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The TESS-Keck Survey (TKS)

A NASA-Keck Key Strategic Mission Support program

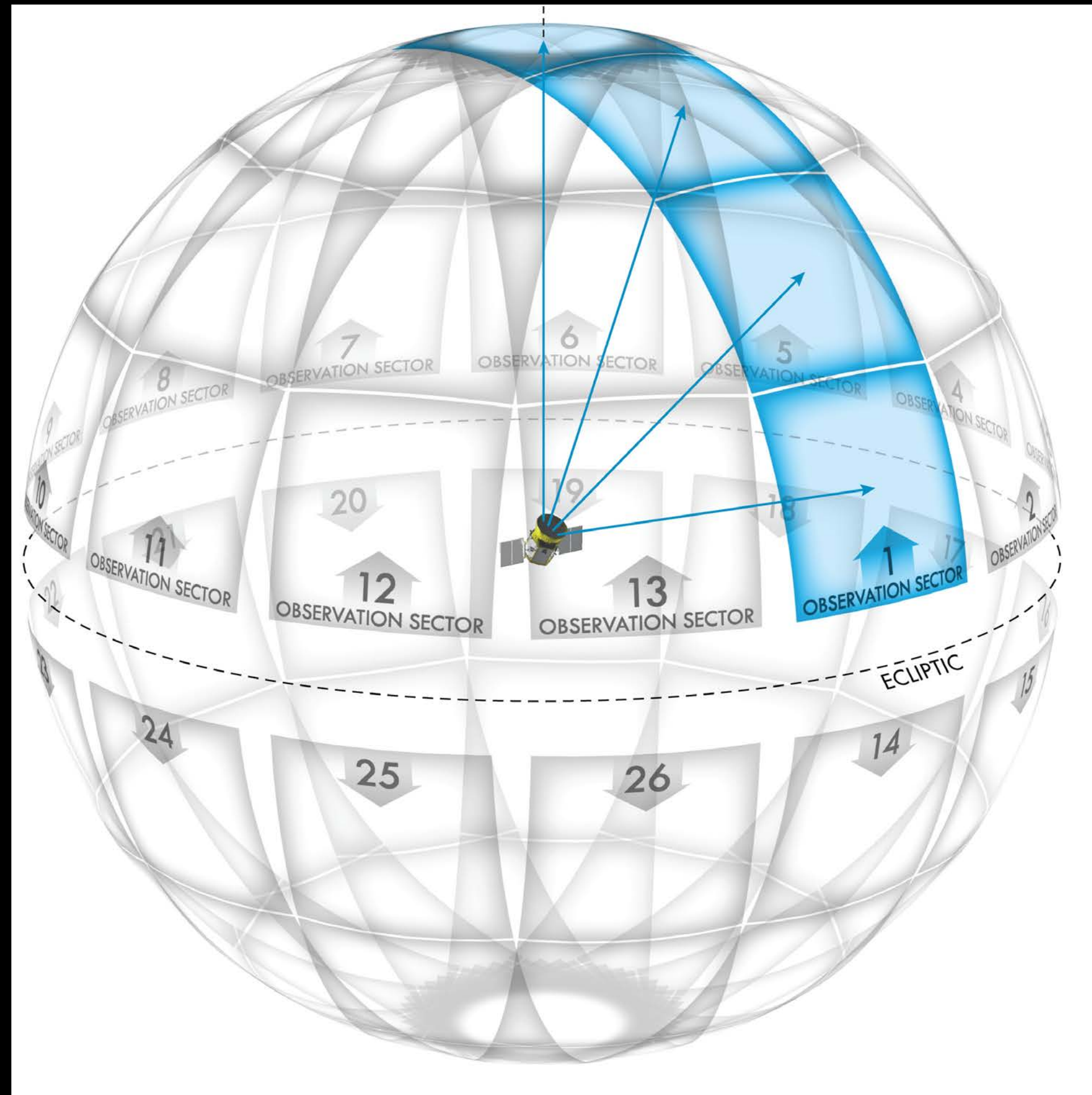
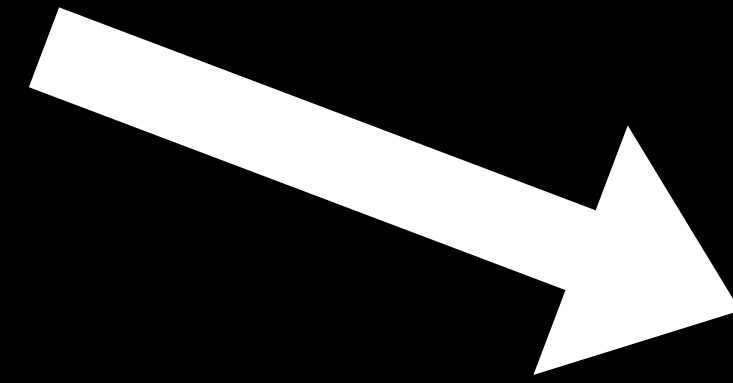
California Institute of Technology – NASA – NASA Exoplanet Science Institute – University of California, Berkeley – University of California, Irvine – University of California, Riverside – University of California, Santa Cruz – University of Hawaii – University of Kansas – W. M. Keck Observatory



We recognize and acknowledge the cultural role and reverence that the summit of Maunakea has within the indigenous Hawaiian community. We are deeply grateful to have the opportunity to conduct observations from this mountain.

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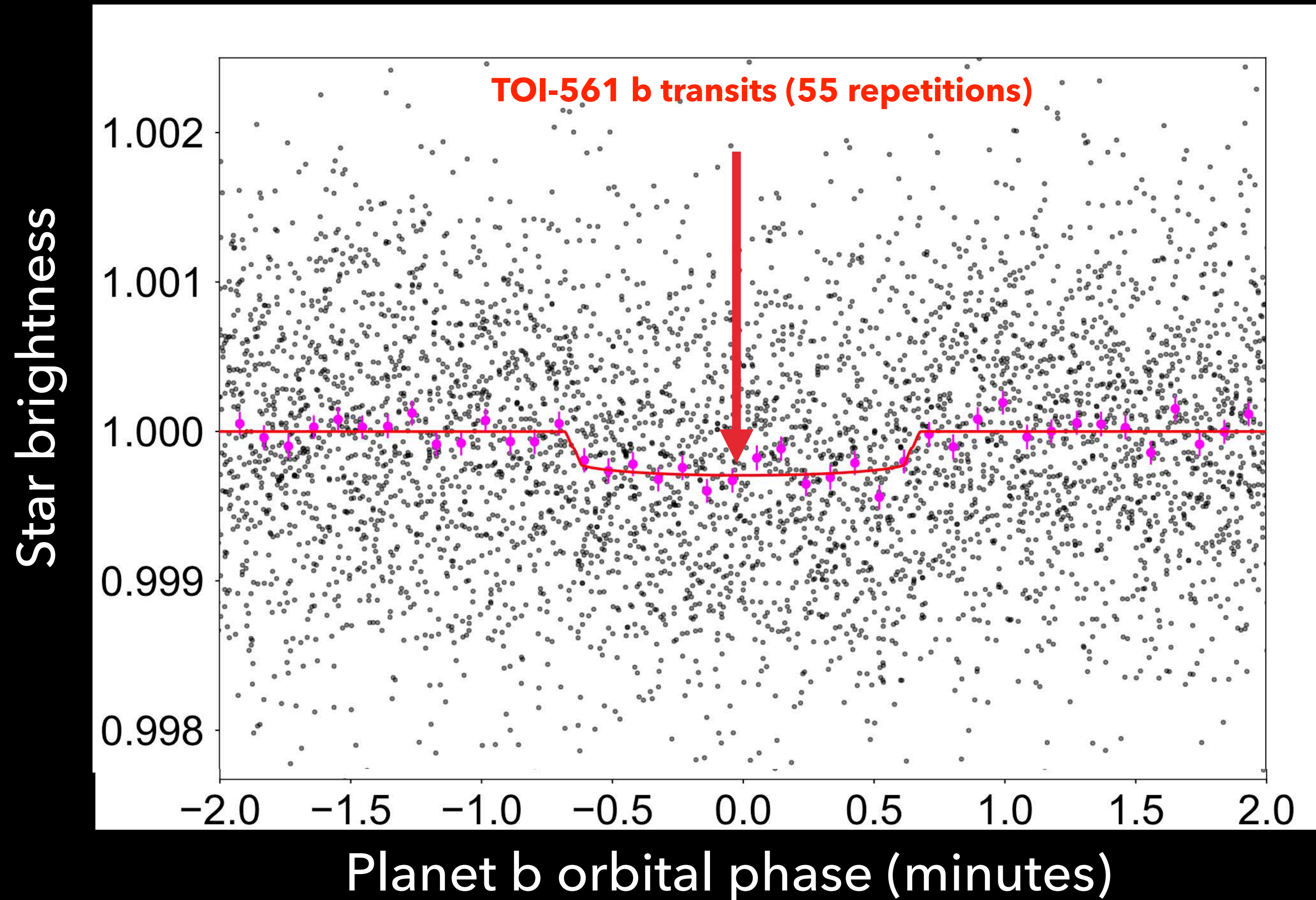
The NASA TESS Mission: searching for planets around the nearest stars



The NASA TESS-Keck survey: measuring masses of small planets found by TESS

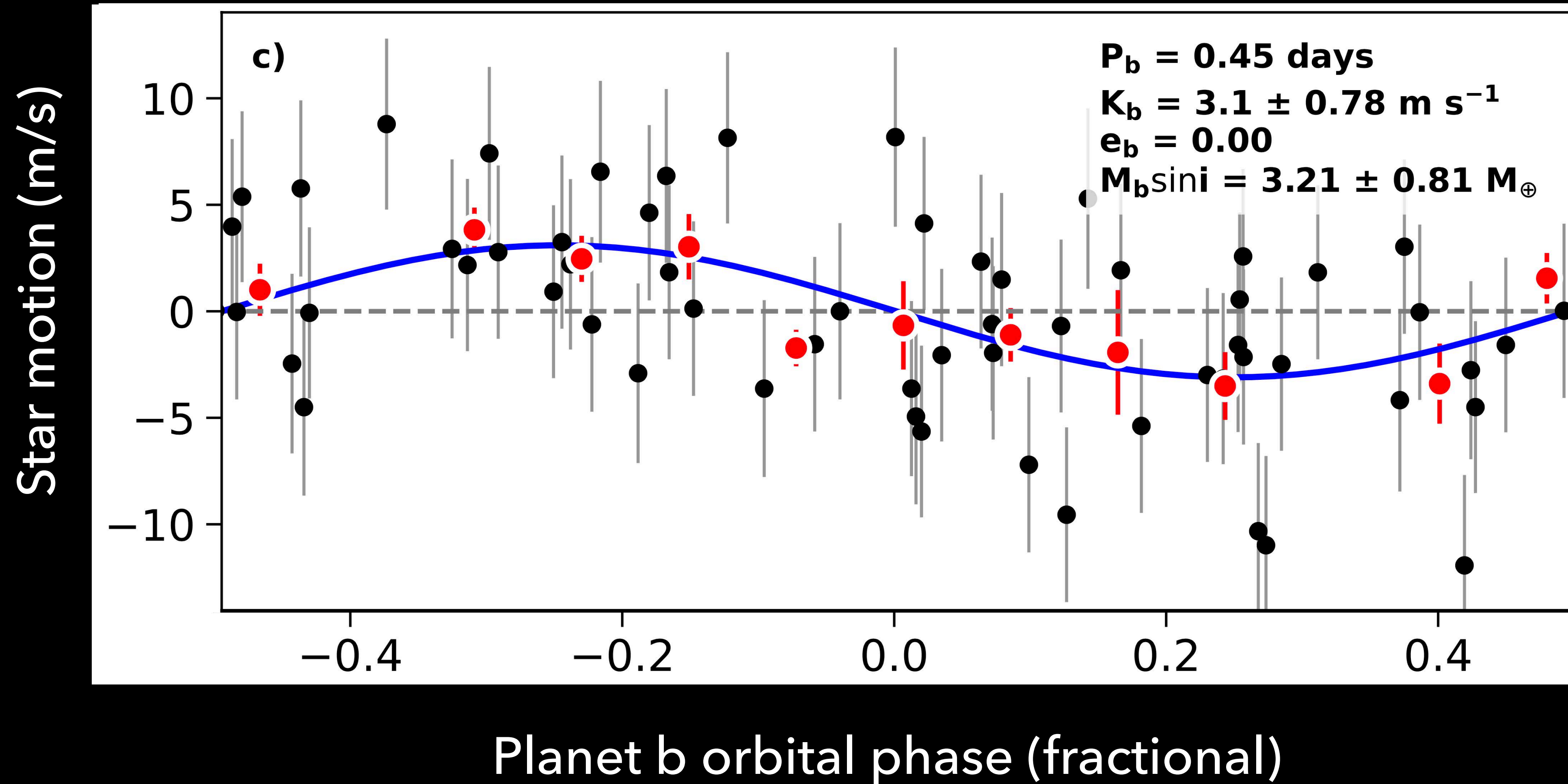


TESS data indicate a small planet orbiting the star every 0.45 days



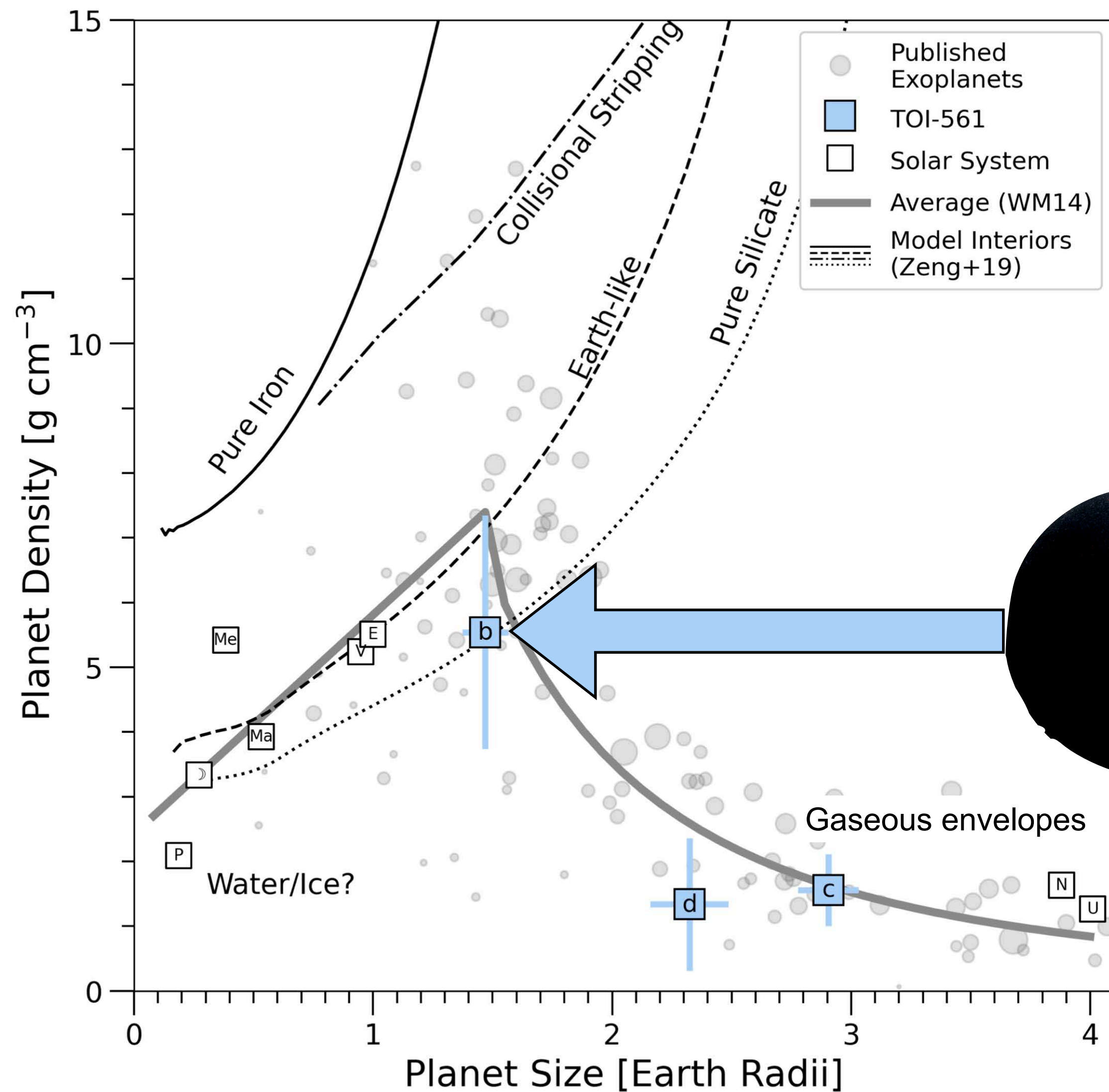
Diminished star brightness during 55 planet transits

Keck data confirm the orbit of the planet and reveal its mass



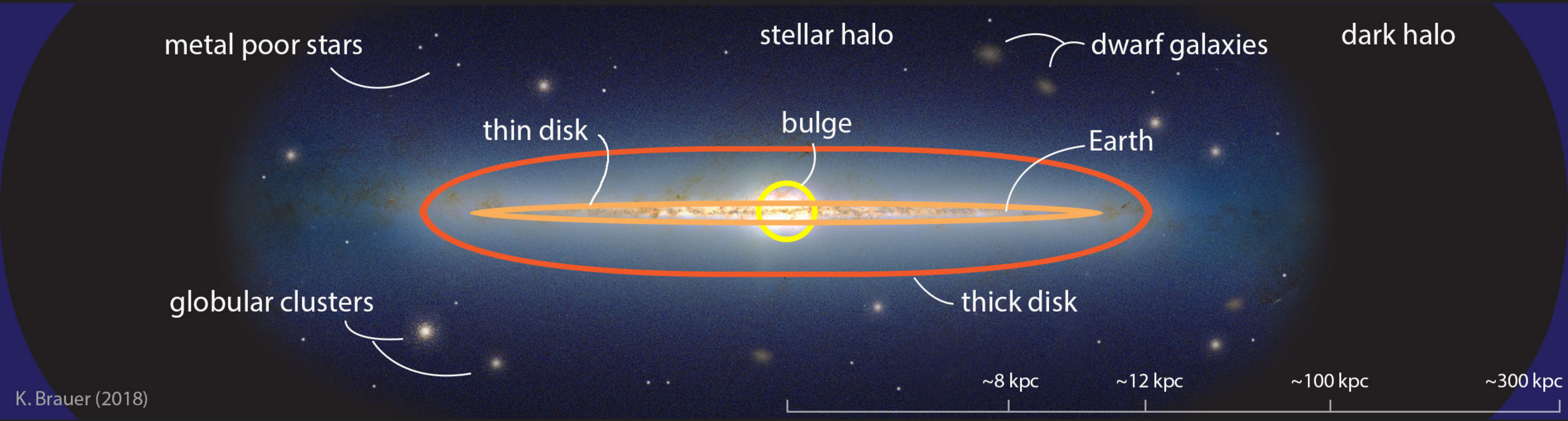
Stellar reflex
motion
corresponding
to the planet's
orbit

TOI-561 b is a rocky magma world



- ▶ Size = 1.45 ± 0.11 Earth radii
- ▶ Mass = 3.2 ± 0.8 Earth masses
- ▶ Density = 5.5 ± 1.8 g/cc
- ▶ Orbital period = 0.45 days, surface temperature = 2500 K
 - ▶ magma ocean on star-facing hemisphere?
- ▶ The other planets have gaseous envelopes

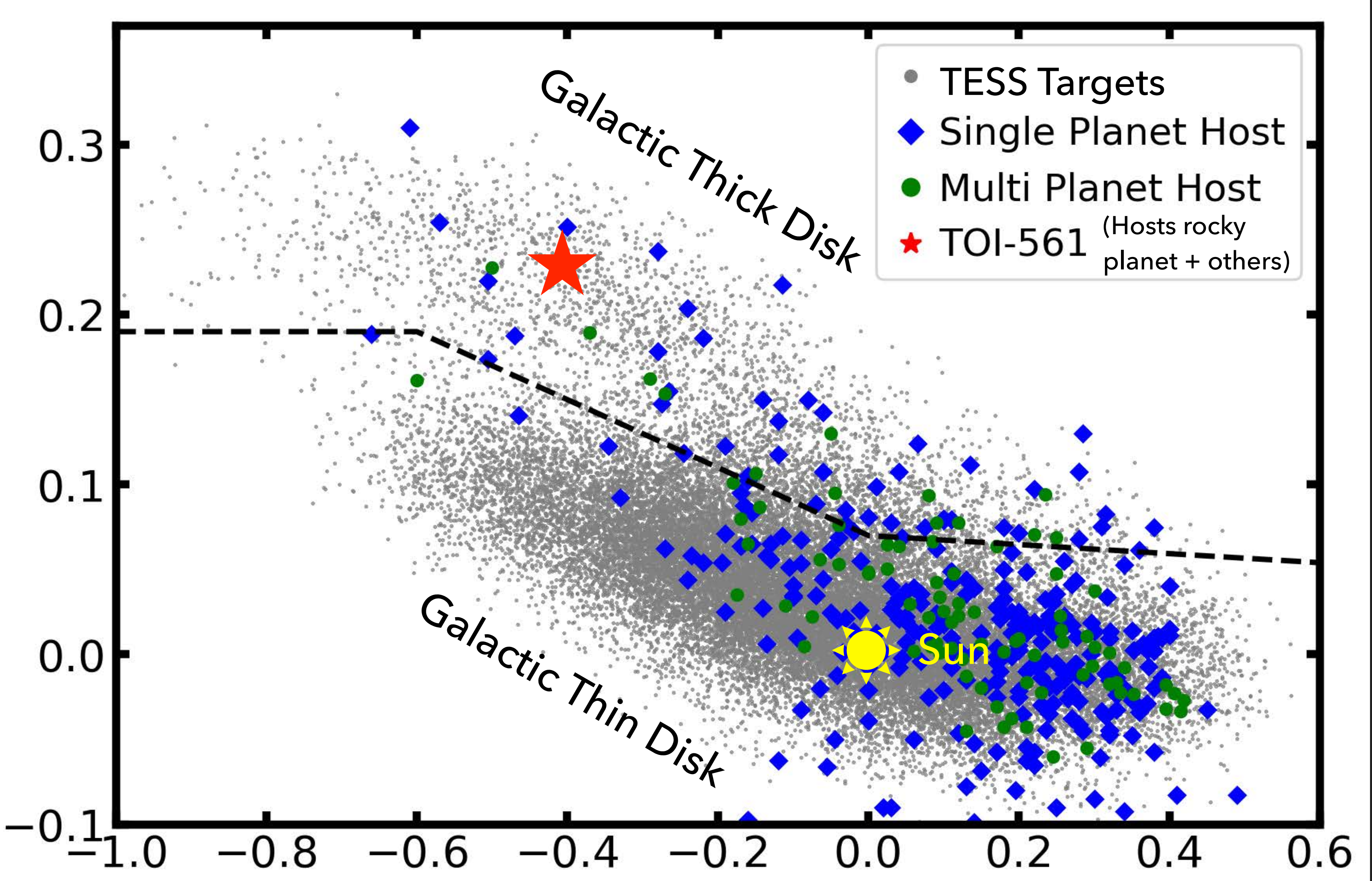
The planetary system orbits a star in the Milky Way Galaxy's sparsely populated, ancient "thick disk"



K. Brauer (2018)

Keck data reveal the star's thick disk membership and age through its chemistry

Abundance of non-iron metals



Stellar chemistry is linked with age:

Sun = 4.5 billion years old

TOI-561 = 10 billion years old

Milky Way Galaxy = 12 billion years old

Universe = 14 billion years old

Abundance of iron

Summary: a rocky planet and its siblings from the dawn of the Milky Way galaxy

- ▶ TOI-561 hosts a rock-and-magma planet and at least two gas-enveloped planets detected by the NASA-TESS Mission and confirmed by the TESS-Keck Survey.
- ▶ The star belongs to the galactic thick disk, a chemically unusual population of stars that are 10 billion years old.
- ▶ TOI-561 b is the first planet with a confirmed rocky composition around such an old star, demonstrating that rocky planets have been forming for most of the history of the universe.

